A new equation to correct the visible and near IR bands of the AVHRR Pathfinder data set for ozone absorption and Rayleigh scattering taking into account the updated solar zenith angles.

Satya Kalluri
(3.11.96)

The accurate atmospheric correction equation which should have been used in the Pathfinder data set to correct ozone absorption and Rayleigh scattering following Gordon et al. (1988) is:

$$\rho_{o,r}(\theta_s,\theta_v,\varphi) = \frac{\dfrac{\pi L_{(\theta_s,\theta_v,\varphi)}}{\mu_s F_o} - \dfrac{\pi}{\mu_s} \bullet I(\theta_s,\theta_v,\pi-\varphi) \bullet \dfrac{1-\exp(-\tau_r/\mu_v)}{1-\exp(-\tau'_r/\mu_v)} \bullet T_o}{T_o \bullet T_r} \tag{1}$$

where

L	is the calibration radiance at sensor
I	is Rayleigh scattering intensity from Gordons paper
T_r	is the transmission function of atmosphere with Rayleigh scattering
T_o	is the transmission function of atmosphere with ozone
μ_s	is the cosine value of the solar zenith angle
μ_v	is the cosine value of sensor zenith angles
F_o	is the solar spectral irradiance above the atmosphere with a unit of (Watts/m^2 μm)
$\rho_{o,r}(\theta_s,\theta_v,\varphi)$	is the surface directional reflectance with ozone and Rayleigh scattering corrections

Following Gordon et al. (1983), the total transmission function for ozone (T_o) after two trips in the atmosphere is approcimated as:

$$T_o = \exp(-\tau_o/\mu_s - \tau_o/\mu_v) \tag{2}$$

However, the optical depth of Rayleigh atmosphere is reduced by a factor of 2 due to diffuse transmission, and the Rayleigh transmittance is given by:

$$T_r = \exp(-\tau_r/2\mu_s - \tau_r/2\mu_v) \tag{3}$$

Where τ_o, and τ_r are the optical thickness of ozone and Rayleigh in the atmosphere respectively, and μ_v is the cosine of the satellite view angle. While τ_o is estimated from ozone measurments from the TOMS instrumnet, τ_r is defined as:

$$\tau_r = \tau'_r \bullet \exp\left(-\text{altitude}/8434(\text{Atmospheric scale height in meters})\right) \qquad (4)$$

Where τ'_r is atmospheric optical thickness at the sea level, which has a constant value of 0.057 and 0.02 for channels 1 and 2 respectively. The exponential term on the right hand side of Equation 4 is an adjustment to account for the variations in Rayleigh optical thickness as a function of surface elevation.

However, in Pathfinder processing software the formula actually impemented for calculating the surface reflectance with ozone and Rayleigh scattering corrections was:

$$p_{path} = \frac{\dfrac{\pi L_{(\theta_s,\theta_v,\varphi)}}{F_o} - I' \bullet \dfrac{1-\exp(-\tau_r/\mu_v)}{1-\exp(-\tau'_r/\mu_v)} \bullet T'_o}{T''_o \bullet T'_r} \qquad (5)$$

Where

μ'_s = cosine of the wrong solar zenith angle in the Pathfinder data base (θ'_s)

$I' = I(\theta'_s,\theta_v,\varphi)$

$T'_o = \exp(-\tau_o/\mu'_s - \tau_o/\mu_v)$

$T''_o = \exp(-\tau_o/\mu'_s)$

$T'_r = \exp(-\tau_r/\mu'_s) \bullet \exp(-\tau_r/\mu_v)$

To get (1) from (5), we now have:

$$\rho_{correct} = \frac{\rho_{path}}{\mu_s \bullet \exp(-\tau_o/\mu_v)} \bullet \frac{T'_o \bullet T'_r}{T_o \bullet T_r} + \left\{ \frac{1-\exp(-\tau_r/\mu_v)}{1-\exp(-\tau'_r/\mu_v)} \bullet \frac{1}{T_r\,\mu_s} \left[\frac{I' \bullet T'_o}{T_o} - \pi I \right] \right\} \quad (6)$$

References:

Gordon, H.R., D.K. Clark, J.W. Brown, O.B. Brown, R.H. Evans, and W.W. Broenkow, 1983, Phytoplankton pigment concentrations in the Middle Atlantic Bight: comparison of ship determination and CZCS estimates. *Applied Optics* **22**:20-36

Gordon, H.R., J.W. Brown, and R.H. Evans, 1988, Exact Rayleigh scattering calculations for use with the Nimbus-7 Coastal Zone Color Scanner. *Applied Optics* **27**:862-871.